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The integration of Situational Awareness Beacon with Reply (SABER) with the Enhanced Position Location Reporting System (EPLRS)

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THESIS

THE INTEGRATION OF SITUATIONAL AWARENESS BEACON WITH REPLY (SABER) WITH THE ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)

by

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December 1996

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SABER is a program initiated by Naval Space Command to provide real-time combat identification (CID) to the tactical user. It uses UHF satellite communications technology in conjunction with the Global Positioning System (GPS) to provide positioning information for up to 500 users.

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The integration of SABER and EPLRS has the potential to serve a major role in the armed services' common goal of reduced fratricide. This thesis gives a detailed description of both systems, examines their individual capabilities and limitations, discusses the ways in which the two systems complement each other, and provides a recommended integrated concept of operations.

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THE INTEGRATION OF SITUATIONAL AWARENESS BEACON WITH REPLY (SABER)WITH THE ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)

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ABSTRACT

In 1992, The Joint Requirements Oversight Council validated a combat identification mission need statement. In support of the requirement for system interoperability, this thesis proposes a concept of operations for integrating two systems, Situational Awareness Beacon with Reply (SABER) and the Enhanced Position Location Reporting System (EPLRS).

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I. INTRODUCTION

A. BACKGROUND

Today's battles increasingly rely on long-range precision guided munitions, with the first combatant to fire often determining the outcome of an engagement. While our ability to shoot first from an over-the-horizon position has decreased the number of casualties suffered by our forces at the hands of the enemy, we must continue to find ways to reduce our number of friendly fire casualties. This need to reduce fratricide has led to the burgeoning field of combat identification (CID). This search for a solution to a battlefield combat identification problem that can be stated as follows: combat identification equals situational awareness plus target identification, or, CID = SA + TID. [Ref. 6]. Situational awareness encompasses the ability to precisely locate friendly forces with respect to each other and must be combined with friend or foe target identification to provide a solution for combat identification. The need for improved combat identification cannot be over-emphasized. The friendly fire casualties suffered during Operation DESERT STORM and the friendly forces shootdown of two Blackhawk helicopters during Operation PROVIDE COMFORT emphasize this need.

In 1992, The Joint Requirements Oversight Council (JROC) validated a combat identification mission need statement comprised of three tiers. The first tier involves the identification of a unit as either friend, foe or neutral. The second tier expands this identification to include identification by platform, type/class and nationality. The third tier addresses interoperability, both joint service and allied. Joint Pub 0-1 defines interoperability as "the ability of systems, units or forces to provide services to and accept

services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together." When applied to communications-electronics systems, this definition is expanded to "the condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users." [Ref. 18, p. 110]

While combat identification systems have long been under the purview of line-of-sight communications systems, space systems have the ability to greatly improve the process of providing situational awareness to both warfighters and their warfare commanders. There are a variety of efforts being undertaken by all of the services to determine the best way to use our space assets to improve combat identification. The Joint Combat Identification Office stresses that while no one system can provide positive identification of friends, foes and neutrals across all environments, there is a definite need for joint service interoperability.

One possible way to improve combat identification is to integrate the Navy's Situational Awareness Beacon with Reply (SABER) system with the Army's Enhanced Position Location Reporting System (EPLRS). SABER is a program initiated by Naval Space Command to provide real-time situational awareness (SA) or combat identification (CID) to the tactical user. It uses UHF satellite communications technology in conjunction with the Global Positioning System (GPS) to provide positioning information for up to 500 users. EPLRS is a situational awareness program used extensively by the Army to support tactical battlefield operations. In addition to providing automatic friendly identification of EPLRS-equipped units, it has a communications capability that allows for

the passage of intelligence and targeting data, messages, and status reports. However, EPLRS operates in a line-of-sight mode only and uses military grid reference system (MGRS) coordinates vice GPS for positional information. The following chapters will give a detailed description of both systems, examine their individual capabilities and limitations, discuss the ways in which the two systems complement each other, and address how they can be integrated to best support the needs of the tactical user.

II. SITUATIONAL AWARENESS BEACON WITH REPLY (SABER)

A. MISSION OVERVIEW

SABER was conceived by the Navy as a means of meeting the requirement for over the horizon (OTH) surveillance of high value naval units and targets of interest. Requirements for space-based relay for aircrew rescue, combat identification and logistics tracking utilizing beacon technologies were added to the list of possible SABER uses. The feasibility of a space-based beacon locating concept was demonstrated during joint-service testing in 1992. Following the downing of two United States Blackhawk helicopters during Operation PROVIDE PROMISE in April 1994, the Office of the Chief of Naval Operations directed Naval Space Command to lead the development and testing of the SABER system. Additional testing has further demonstrated SABER's capability to serve as a near-term solution for friendly force situational awareness/combat identification requirements.

SABER provides a space-based capability to locate and identify friendly forces utilizing Global Positioning System (GPS) positioning data. This positional information is combined with platform information and is disseminated to tactical units and global command and control nodes via UHF line-of-sight nodes and UHF satellite communications. This combination of friendly force situational awareness with identification of friendly combat assets directly supports the combat identification mission. SABER is based on the concept that fratricide will be greatly reduced if warfighters know their own positions, as well as their fellow warfighters' positions, and can communicate

this information up the chain of command and to their allies. The SABER program has been divided into phases as summarized in Table 1. It is an ACAT II program with the Milestone II Review scheduled for the third quarter of FY97. [Ref. 23] The current phase focuses on integrating SABER with EPLRS and demonstrating SABER's ability to utilize the Cobra waveform, a communications waveform that will improve SABER's low probability of intercept (LPI) capabilities.

PHASE	DATES	PURPOSE/OUTCOME
I Concept Formulation and Development Planning	MAR 94 - JUL 94	1. UHF chosen as the best frequency band for relay of beacon data. 2. GPS chosen for geolocation. 3. Under the JROC cost constraint of $5,000, decided to design and manufacture a fully functional beacon.
II Engineering Demonstration Model Design	AUG 94 - NOV 94	1. Continued feasibility tests. 2. Concluded product surveys. 3. Began detailed design and engineering of hardware and software. 4. Ended with a Preliminary Design Review.
III Fabrication of Engineering Prototype System Components and Field Demonstration	AUG 94 - MAY 95	1. Produced 5 SABER beacons. 2. Produced 2 C2 terminals. 3. Performed readiness testing of the EP system. 4. Conducted SABER technical evaluation. 5. Prepared Demonstration Report.
IV Design, Fabrication and Test of the Operational Demonstration (SABER-0) System	MAR 95 - SEP 95	1. Conducted a Critical Design Review. 2. Prepared detailed design and engineering of hardware and software. 3. Prepared an operator's manual. 4. Constructed 27 beacons and an additional C2 terminal. 5. Installed these beacons on 27 platforms. 6. Participated in ASCIET 95. 7. Conducted an acceptance test of SABER-0. 8. Prepared final demonstration report.
V Follow-on Logistics Support & Training for Existing Beacons	SEP 95 - JUL 96	1. Deployed SABER beacons and terminals with MEU-22.
VI Cobra Waveform Demonstration and EPLRS Integration	MAY 96 - DEC 96	1. Displayed integration with EPLRS in ASCIET 96. 2. Cobra waveform demonstration scheduled for DEC 96.

Table 1: SABER Development Phases [Ref. 21].

B. COMPONENTS

The SABER system is comprised of three segments; beacon, space and command and control, which are described below.

1. Beacon Segment

The beacon segment consists of a miniature UHF transceiver that is capable of both satellite communications (SATCOM) and line-of-sight (LOS) communications, a digital signal processor, an integrated commercial grade ("CA code") GPS receiver daughter board, a microprocessor, and a power management subsystem.

The beacon assembly is contained in an electronics housing that is sealed to withstand dust and water immersion (up to one meter immersion for one hour). The entire beacon assembly measures 8" by 3.25" by 10 " and weighs eight pounds. It is intended to be rapidly installed in many types of platforms. The nominal temperature range is 0-50 degrees Centigrade. The beacon periodically transmits the host platform's identification code, current location, altitude, speed over ground, course over ground, and time to the controller and all listening SABER beacons. The beacon is designed to support up to five simultaneous networks using a mix of SATCOM and LOS channels. The host platform must provide access to power and connections to GPS and UHF antennas. Figure 1 is a picture of a SABER beacon.

UHF transceiver components include a radio frequency (RF) power amplifier, a transmit/receive switch, analog receiver and transmit/receive oscillators. The transceiver is capable of tuning 15,000 UHF frequencies in 5 kHz steps from 243.0 MHz to 318.0 MHz. This range includes all available SATCOM uplink and downlink frequencies. It can also tune over 5000 discrete UHF LOS frequencies. The receiver has

a maximum noise figure of 2 dB. The first local oscillator is capable of binary phase shift keying (BPSK), shaped BPSK and frequency shift keying (FSK) modulation with a maximum rate of 9600 symbols per second.

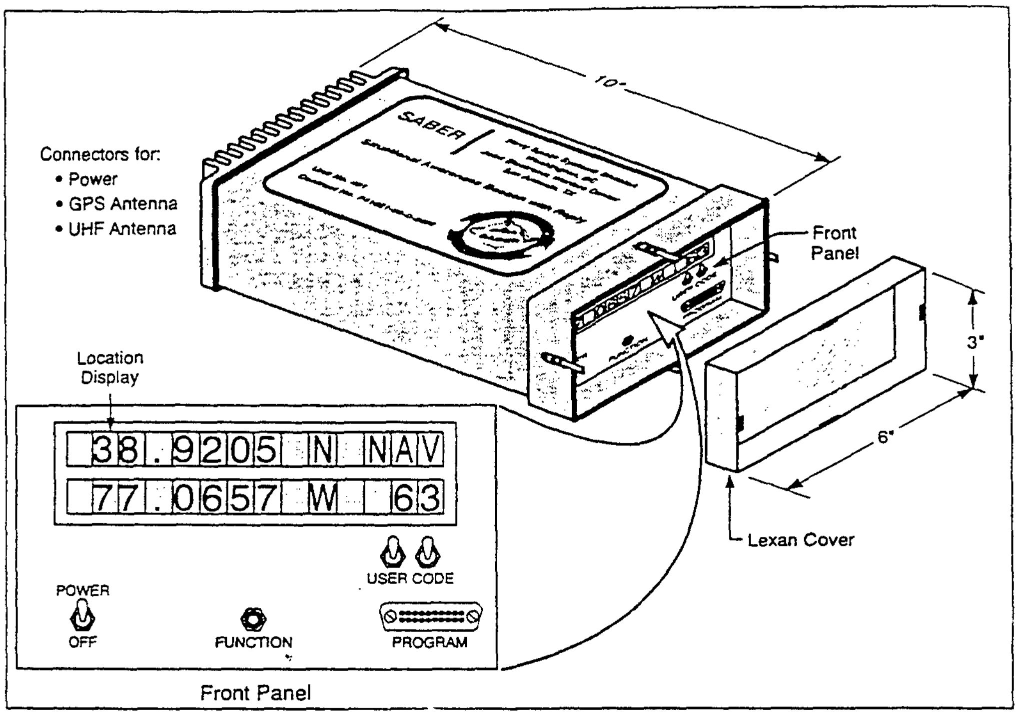


Figure 1: SABER Beacon. [from Ref. 6]

A microprocessor controls the digital signal processor (DSP) functions and schedules beacon operation. The DSP processes the transceiver signal for incoming and outgoing messages. It produces a shaped BPSK waveform that is transmitted using Time Division Multiple Access (TDMA) techniques. Beacon operation, including assigned transmission interval and operating frequency, is normally scheduled via over-the-air commands by a network controller at a command and control (C2) node. A laptop computer acts as a simulated weapon system interface to the beacon, allowing the host

platform user to display situational awareness information, query other units for friendly identification and response, and manipulate beacon operating parameters. These computer display terminals (CDTs) allow operators to monitor and display reports from other SABER-equipped units. Figure 2 shows a sample SABER CDT.

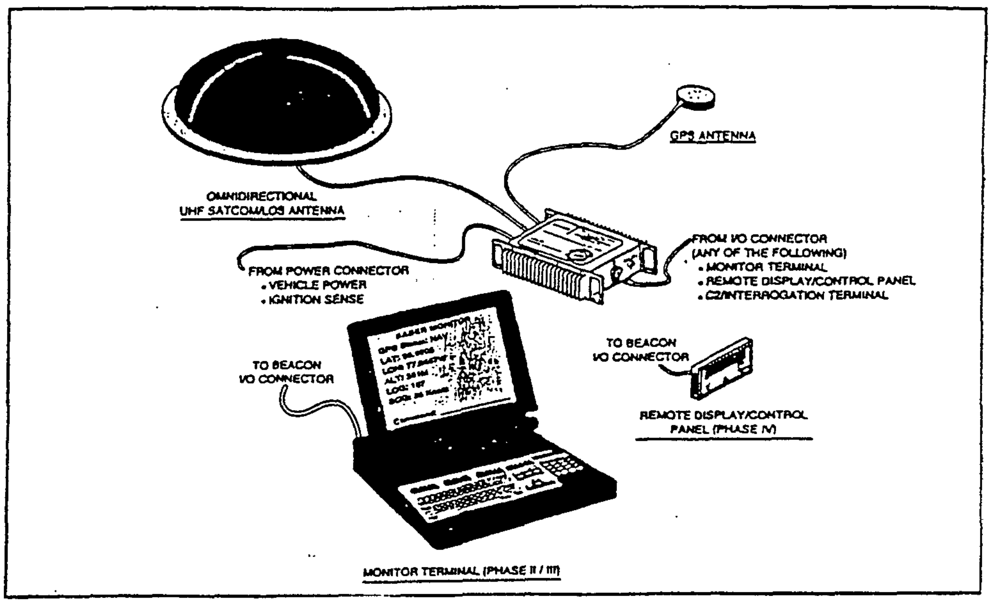


Figure 2: SABER CDT. [From Ref. 7]

2. Space Segment

SABER uses existing space assets: 25 KHz and 5 KHz channels on Fleet Satellite Communications (FLTSATCOM and UHF Follow-On (UFO)) spacecraft. The function of the space segment is to (1) relay beacon-originated messages to tactical/theater users and MILSATCOM gateway nodes and (2) relay SABER cueing/reprogramming commands to beacon units. [Ref. 6] The satellites used by SABER provide worldwide

coverage, except for the polar regions, and provide enhanced redundancy and endurability for the users. Figure 3 shows FLTSATCOM coverage. LOS transmissions are used to supplement SATCOM transmissions.

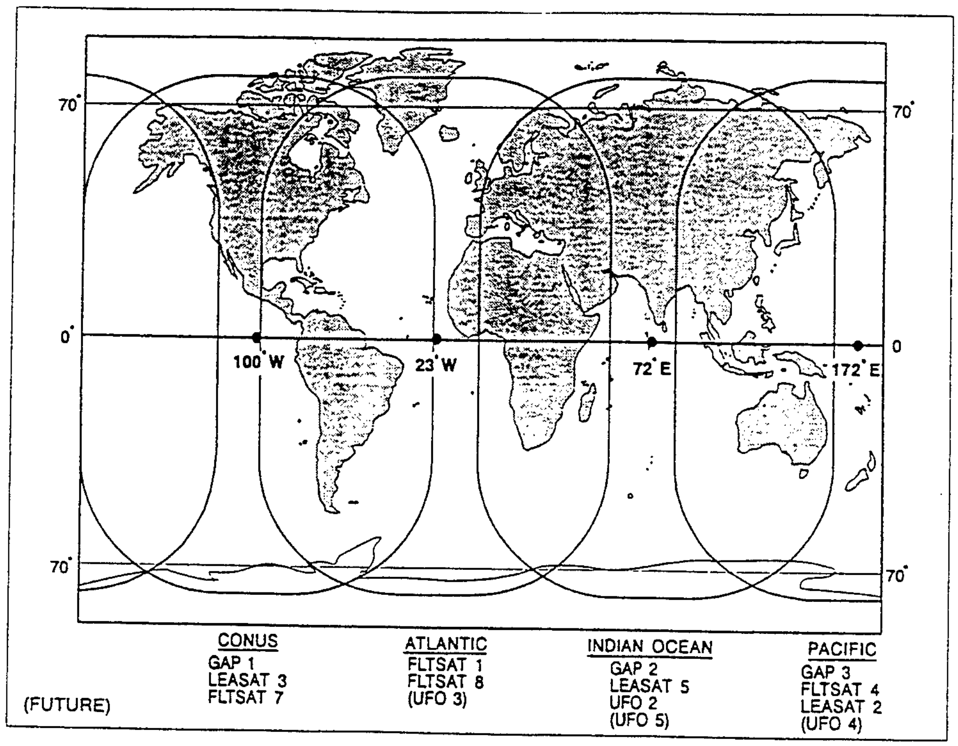


Figure 3: FLTSATCOM Coverage Area. [From Ref. 6]

3. Command and Control (C2) Segment

The C2 segment consists of fixed-site network management terminals. Each SABER network is associated with a separate satellite transponder and is managed by a separate network controller. The network controller schedules TDMA transmissions for all users on a given SABER network, displays user data on a TAC-3 or TAC-4 computer, commands beacon operation over-the-air, polls units for individual immediate reports, and transmits new crypto or cipher keys to the beacons. The controller uses Navy

standard Joint Maritime Command Information System (JMCIS) software and translates/reformats SABER messages into the OTH-gold message format to transmit SABER data to other users through the OTCIXS network. Another translator reformats the data into the TADIL-J format for transmission to JTIDS/Link-16 users.

C. CAPABILITIES

SABER can operate in one of two display modes - Local Situational Awareness (LSA) or Friendly Identification (FID).

1. Local Situational Awareness (LSA)

The LSA mode provides a "snapshot" of the battlefield. It allows the operator to observe all reporting SABER units within a specified range on a grid coordinate or latitude/longitude display. This matrix is overlaid with the current positions of the operator and all other SABER users reporting on the network. It shows the direction of travel of the host and the true bearing, range and direction of travel of all other displayed SABER reporters and can be configured to show line-of-sight situational awareness on a scalable display. Additional backup screens provide position, speed over ground, course over ground, true bearing and range, and identification of the displayed reporting units. LSA provides the operator immediate knowledge of his position and movement in three dimensional space and in relation to other SABER equipped units within LOS or SATCOM range. [Ref. 14] Figure 4 provides a sample LSA display.

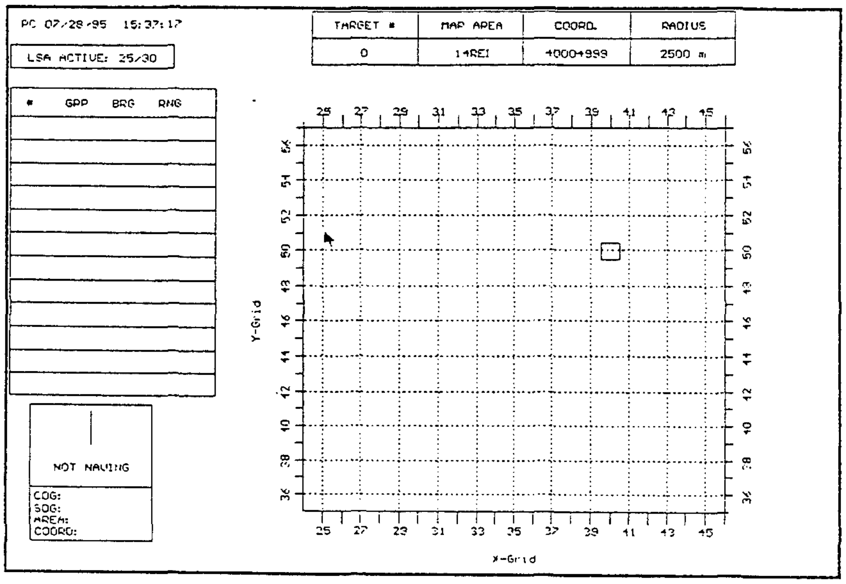


Figure 4: LSA Display. [From Ref. 7]

2. Friendly Identification (FID)

The FID mode interrogates designated target locations to provide positive identification of friendly forces. It functions as an Identification Friend or Foe (IFF) query and response system that polls SABER-equipped units to determine the location of friendlies in a specific geographic location. Figure 5 provides a sample FID display.

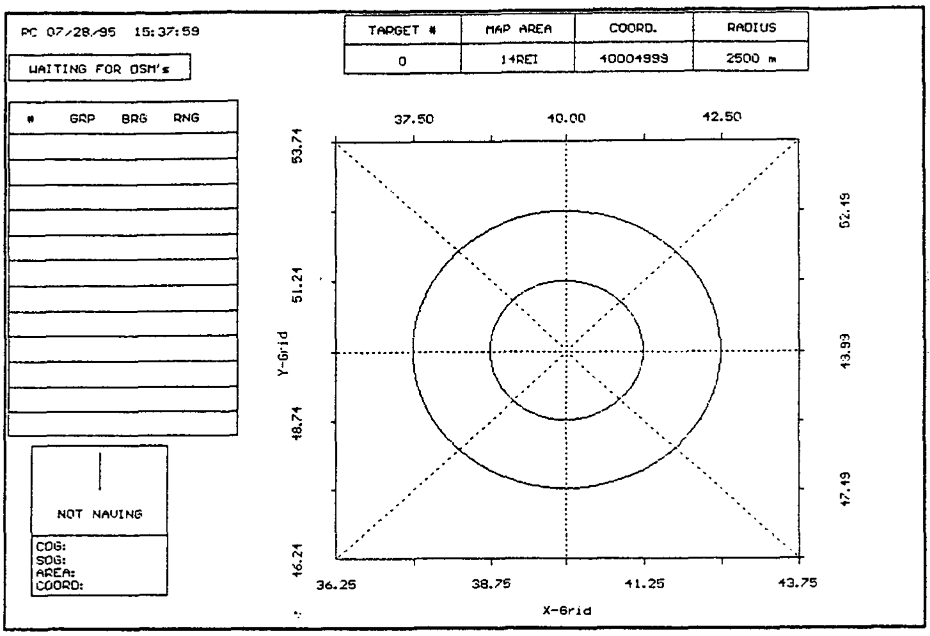


Figure 5: FID Display. [From Ref. 7]

To use the FID mode, the user selects a weapon targeting point and radius of weapon lethality. He then sends an "Intent to Shoot" (ITS) message that is transmitted omnidirectionally to all users within his LOS. Upon receiving an ITS message, a beacon compares its own location with the kill zone cited in the ITS. SABER-equipped friendly units within this zone respond with a "Don't Shoot Me" (DSM) message. Figure 6 depicts this ITS-DSM concept. DSM responses from units within and near the designated impact zone are displayed on the shooter's CDT as a friendly position location less than two seconds after the shooter has designated a target. This capability allows the user to positively ascertain the presence of friendly units in a targeted area prior to shooting and

can greatly improve the air-to-ground and ground-to-ground fire control problem, eliminating the primary sources of fratricide. [Ref. 14]

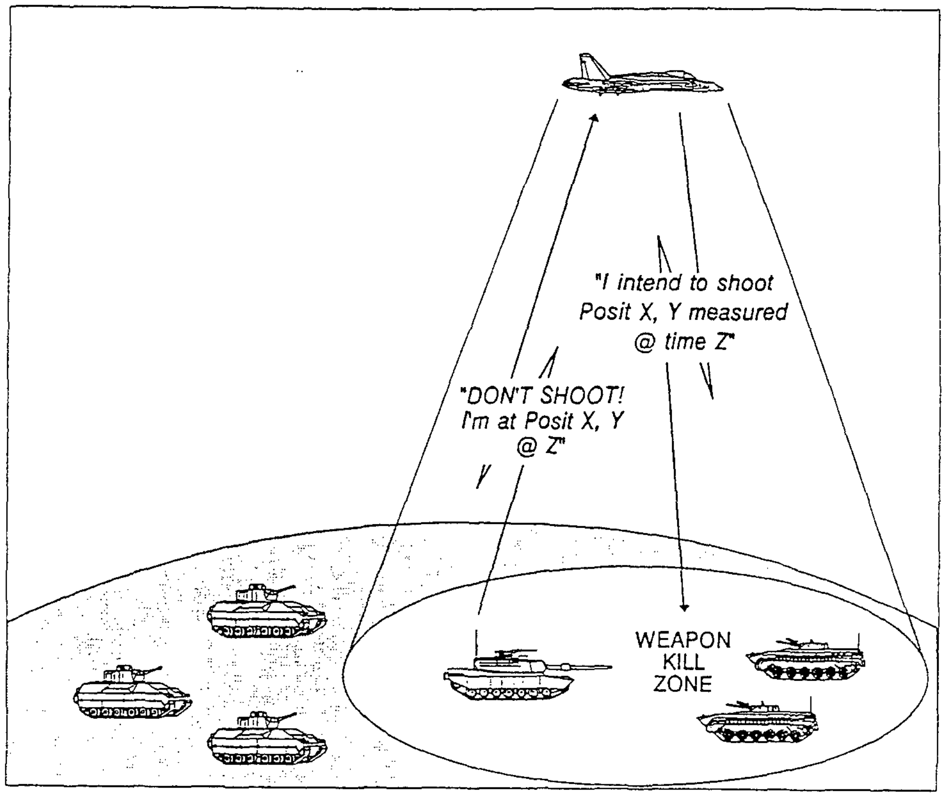


Figure 6: FID DSM Concept. [from Ref. 8]

3. Capacity

Each individual beacon can operate concurrently on several different networks, such as a global situational awareness net, theater situational awareness net, "Don't Shoot Me" (DSM) net and up to eight theater LOS nets.

Each 25 KHz SATCOM network can support up to 500 position reports every two minutes. The structure is variable and can range from allowing 500 users one report every two minutes to allowing one user to report 500 times in two minutes. The network can be structured to provide a variety of reporting rates for a total of 60,000

position reports per hour. Each 5 KHz SATCOM channel can support up to 150 reports every two minutes.

Each theater LOS network can support up to 16 UHF LOS reports per second. Each user can display up to 200 simultaneous tracks. The battlefield commander can automatically monitor up to 15,000 platform positions per hour per net. Each beacon has a buffer capacity of 8,464 records. [Ref. 14]

4. Electronic Counter Countermeasures

To mitigate the probability of the enemy exploiting and interfering with either direct or satellite-relayed beacon transmissions, SABER beacons use LPI burst message transmissions, embedded message enciphering and over-the-air cryptologic rekeying. Additionally, beacon units use 24-hour authentication and validation codes to alert other system users to the possibility that a unit has been captured. [Ref. 6]

D. OPERATIONAL FEATURES

1. SABER Interfaces

SABER messages are received by tactical terminals via LOS and SATCOM transmissions or via theater tactical dissemination broadcasts, including TRAP, OTCIXS and TADIL-J. The SABER command and control terminal (C2T) translates SABER reports to TADIL-J format for Link 16 transmission or injection into the JTIDS network. Command and control gateway nodes also process beacon information for further dissemination via the Defense Data Network (DDN) and the Defense Information System Network (DISN), which provide the backbone for disseminating this information to global C2 systems, including JMCIS and GCCS. [Ref. 14]

2. Messages

Each SABER message has a duration of 182 msec and is comprised of 16 bytes: a three-byte header that specifies the message type and beacon identification code, a twelve-byte message, and a one-byte checksum that is calculated by XOR-ing the header and message bytes. [Ref. 14] SABER message types include the following:

- Position Report
- Command Acknowledgement
- Beacon Identification Code
- Network Protocol Specification
- Network Reporting Specification
- RF Transmitter Specification
- RF Transmitter Mute and Enable
- Polling Request
- Intent to Shoot Message
- Don't Shoot Me Message
- Network Cipher or Encryption Seed.

3. TDMA Network Structure

SABER uses Time Division Multiple Access to allow the C2 terminals to simultaneously track and control a number of beacons. The potential loss of positional data is minimized by designating beacon reporting times prior to operation. The SABER SATCOM protocol has a TDMA major frame of ten minutes. Each major frame is divided into 50 minor frames that are comprised of either twelve one-second slots or 24 0.5-second slots, for a total of 600 one-second slots or 1200 0.5-second slots. There are

six major frames in an hour and 144 major frames in 24 hours. The data rate for SATCOM is 2400 symbols per second. [Refs. 14 & 24]

The TDMA protocol for LOS communications consists of minor frames that are comprised of 24 slots each. The duration of a LOS slot is 500 msec, giving a total of 1200 slots per major frame. The data rate for LOS communications is 4800 symbols per second.

The TDMA protocol for FID messages is similar to that used for SATCOM and LOS messages. Each FID minor frame is comprised of 12 slots of 500 msec each. The slots are used as follows:

Slot 1: Transmission of ITS command.

Slot 2: Reserved for processing ITS message.

Slots 3-12: Transmission of DSM messages.

E. SABER IMPROVEMENTS

Follow-on versions of SABER, designated SABER-0.5 and SABER-1, will improve on the initial SABER-0 prototype. The upgraded versions will have an increased frequency range, added ECCM capabilities, increased maximum number of users and increased positional accuracy. Table 2 compares SABER-0, SABER-0.5 and SABER-1.

SPECIFICATION	SABER-0	SABER-0.5	SABER-1
Power	15-35 Vdc 15 W receive 200 W transmit	same with enhanced power management for manpack operation	same with enhanced power management for manpack operation
Frequencies	243-318 MHz	243-318 MHz	243-400 MHz
ECCM	Burst, FEC	same plus COBRA waveform, frequency agile	same plus NSA certified crypto
Software displays	JMCIS, Unified Build, Military and Commercial maps at C2 Terminal	same plus military and commercial maps on CDT and TALON TAC-4 C2 terminal	same
Max Number of Users SATCOM: LOS:	 3,000 positions/hour 6,000 positions/hour	 15,000 15,000	 15,000 60,000
Transmission Interval	Flexible, seconds to minutes	Flexible, as fast as 200 msec SATCOM/LOS	Flexible, as fast as 200 msec SATCOM, 50 msec LOS
Temperature Range	-5C to +50C	-15C to +65C	TBD
Output Signal Power Burst: SATCOM: LOS:	 25 W 750 msec 375 msec	 25 W 200 msec 200 msec	 25 W 200 msec 50 msec
Transmitter	TDMA with 1 sec SATCOM timeslot and 0.5 sec LOS slot; FDMA, 243-318 MHz	Faster TDMA with 200 msec SATCOM/LOS slot, COBRA waveform	TDMA with 200 msec SATCOM slot, 50 msec LOS slot, COBRA waveform, 243-400 MHz, FID Guard Receiver
GPS Method	C/A Code	P(Y) Code	P(Y) Code
Positional Accuracy	100m SEP	<16m SEP when keyed	<16m SEP when keyed
Communication Ports	RS-232	same plus KYK-13/ KOI-18	same plus MIL-STD-1553B

Table 2: Summary of SABER upgrades [After Ref. 13].

III. ENHANCED POSITION LOCATION REPORTING SYSTEM (EPLRS)

A. MISSION OVERVIEW

1. System Description

The Enhanced Position Location Reporting System (EPLRS) is one element of the Army Data Distribution System (ADDS). EPLRS supports tactical operations on the battlefield using a reliable digital data communications system to link mobile battlefield elements to higher echelons of command. Its capabilities include automatic position location, reporting, friendly identification, and navigation. The positions of units equipped with EPLRS are known and available to authorized individual users and to command and control facilities, allowing for quick identification of friendly units and greatly reducing the probability of fratricide. The system allows the passage of targeting data, combat orders, situational reports (SITREPS), intelligence data, and messages without taxing other operational communications links. It allows adjacent fighting elements, even in different organizations, to "see" and communicate directly with each other.

2. Capabilities

The various capabilities of EPLRS enable it to be utilized in support of all five mission areas of the battlefield: maneuver control, fire support, air defense, intelligence/electronic warfare and combat service support. [Ref. 2]

a. Maneuver Control

Unit identification, position location and unit operational status can be distributed to command and control centers, giving the commander a snapshot of the forces and assisting in decisions to deploy and maneuver these forces.

b. Fire Support

EPLRS benefits the fire support mission by distributing artillery fire requests and mission support data simultaneously to multiple destinations. An artillery request initiated by a forward observer can be automatically routed to the fire support team, fire direction center, fire support officer and the battery computer system, enhancing mission processing and improving response times while reducing operator workload and transmission error.

c. Air Defense

EPLRS provides reliable communications to support the timely distribution of command and control data and the exchange of air track data, provides data communications for air tracks from sensors to fire units, and can provide sensor netting communications.

d. Intelligence/Electronic Warfare

EPLRS supports the intelligence/electronic warfare mission by allowing the rapid collection of data from widely dispersed systems in the forward battle areas, processing it, then disseminating the data back to the deployed forces. The system automatically reconfigures itself to overcome line-of-sight limitations and jamming and allows the commander to modify the network to accommodate tactical deployment changes.

e. *Combat Service Support*

Logistics support operations are greatly enhanced by the position location/reporting navigation functions of the system. The efficiency of coordinating medical evacuations, convoy control and emergency repairs of disabled vehicles is improved by the features of this system.

B. COMPONENTS

The two primary equipment elements are the Network Control Station (NCS) and the Radio Set (RS).

1. Network Control Station

The NCS is the focal point for automated technical control and centralized management of an EPLRS network comprised of up to 400 radio sets. It is operated by the signal battalion within the division and provides dynamic network management, automatic processing of position, navigation and identification, responses to information requests from participating users, and a real time display and control capability. It provides the control functions necessary for user-to-user communications, including assignment of timeslot and frequency resources, establishes and maintains EPLRS control and communications networks, and monitors and reports systems performance information. It activates/deactivates permanent virtual circuits, or needlines, provides over-the-air rekeying (OTAR) of cryptographic variables and acts as an alternate NCS for adjacent EPLRS communities. Each NCS is linked to an Army command and control center via a duplex communications circuit and to two alternate NCSs via a 160 bps duplex needline. The NCS requires an input power of approximately 15 Kilowatts at 120

VAC, 60 Hz which can come from either facility house power or an external generator. [Ref. 2]

Currently, the NCS is a fully militarized shelter which is mounted on a five-ton vehicle. Figure 7 is a picture of an NCS. The layout of the NCS provides space for the equipment as well as the operator and two additional personnel. The equipment suite includes one AN/UYK-7 and three AN/UYK-44 computers, a Display Control Station with a 22-inch display, an Enhanced Command Response Unit (ECRU), crypto control unit, cartridge magnetic tape unit, and an AN/UGC-74. A downsized, lighter weight version that can be mounted on a highly mobile multipurpose wheeled vehicle (HMMWV) is under development.

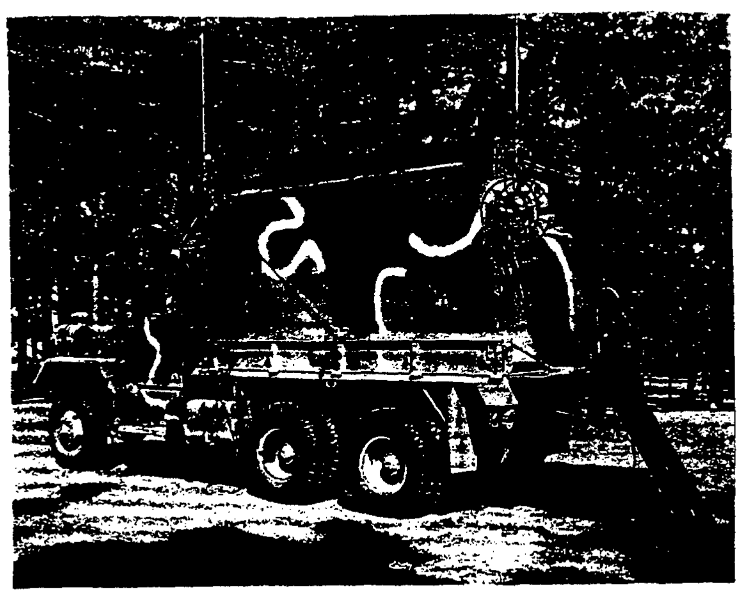


Figure 7: EPLRS Net Control Station. [from Ref. 3]

2. Radio Set

The RS can be configured as a manpack, for vehicular mount or for aircraft. It is a transceiver that reports the identification of other RSs with which it can communicate, provides a barometric transducer reading, has two interfaces (user and computer), operates as a relay and provides data for the NCS to use in computing position and navigation information. [Ref. 2]

The basic unit has dimensions of 5.1 inches by 10.5 inches by 14.7 inches and weighs 28 pounds, allowing for manpack operation in a rugged tactical environment. The same basic unit is used in all configurations, but the battery box is replaced with a Selectable Power Adapter (SPA) for vehicles or an Airborne Power Adapter (APA) for use in aircraft. The host interface configuration is either ADDSI or MIL-STD-1553B. The MIL-STD-1553B interface will be used in airborne and some vehicle applications. It transfers user information in host packets containing up to 60 bytes (480 bits). The ADDSI is designed for emerging and future battlefield automation systems. It transfers user information in host packets containing up to 128 bytes (1024 bits). Figure 8 depicts a radio set.

The RS uses spread spectrum and TDMA technology. The EPLRS TDMA architecture uses 512 time slots per second. The current radio can transmit or receive a fully encrypted packet of 80 user bits in a single time slot. It is a line-of-sight radio that operates on one of eight predesignated frequencies in the 420-450 MHz range. The RS can transmit on any combination of these frequencies or can frequency hop across all of them. It operates on 28 volts direct current which can come from either a battery, a vehicle alternator, or 110-120 volts alternating current. [Ref. 2]

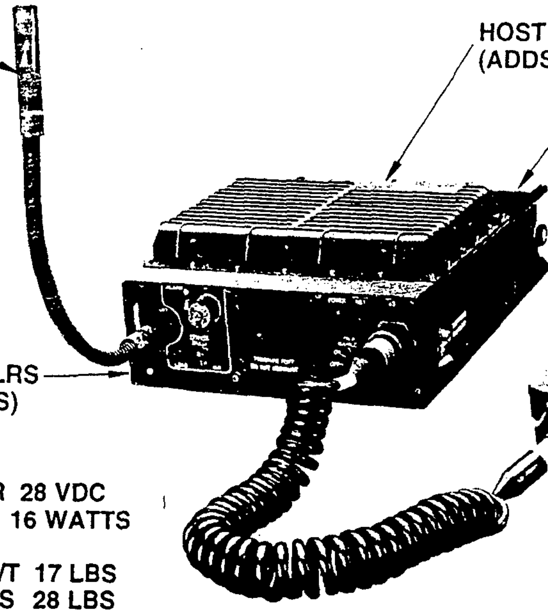


Figure 8: EPLRS Radio Set. [from Ref. 3]

C. CAPABILITIES

1. Position Location

EPLRS computes user position location by multilateration. This method requires that range vectors be determined from at least three known RS locations to locate another RS whose position location is unknown. EPLRS determines these ranges by measuring the time-of-arrival (TOA) of RF bursts from the RS as received by the other RSs. Since the transmission times are precisely known, the TOA is a direct reflection of the path length between transmitting and receiving RSs. The multilateration then uses these ranges to calculate the position.

The data provided in response to an operator's request for his own location uses Military Grid Reference System (MGRS) coordinates, with distance given in meters and bearing given in degrees. Typical accuracy is within a 15 meter Circular Error Probable (CEP). An operator can also request the location of another EPLRS-equipped unit or any of up to 104 Predesignated Items (PDIs). The operator can then receive either an MGRS coordinate or a bearing/range to the RS or PDI location. Requests for position location information can be updated automatically or provided on a one-time as requested basis.

EPLRS is designed so that the NCS operator can authorize any user one-time access to a particular service request or alter the user's library to allow permanent access to an NCS service message net. This provides flexibility to allow for the loss of a unit and the reassignment of another RS in its place. Any RS authorization can be quickly modified by the NCS operator to allow access as needed. Position location accuracy for the various radio sets is summarized in Table 3.

Radio Set Type	X, Y Absolute Horizontal Position Accuracy (CEP)	Z Absolute Altitude Accuracy (AEP)	Radio Set Deployment
Manpack	10 - 30 meters	10 - 30 meters	Primary Operating Area (47 X 47 Km)
Surface Vehicles	10 - 30 meters	10 - 30 meters	Primary Operating Area (47 X 47 Km)
Airborne (all platforms)	25 - 100 meters	10 - 30 meters	Primary Operating Area (47 X 47 Km)
Airborne (all platforms)	100 - 200 meters	15 - 90 meters	Extended Operating Area (300 X 300 Km)

Table 3: Position Location Accuracy for Radio Set Types [From Ref. 3].

2. Identification

A significant feature of EPLRS is its capability to identify individual users. Two different identification service requests are available to the user. The identification, or "I", type provides the unit's military identification (MILID) or name. It is used for verification purposes on the part of the user or when a unit in the system does not have an ID. The who, or "W", type provides the identity of unknown units. The user sends to the NCS either the MGR or the estimated bearing and range of the unknown unit. The NCS will then send the military ID of the unit in question to the requesting RS .

This identification capability can be used by a local security outpost to verify the identity of a returning reconnaissance patrol or by an artillery observer to request information about an unidentified unit. The RS equipped units also have an Identification Friend/Foe (IFF) capability (in addition to traditional IFF techniques).

3. Navigation Aids (NAVAIDS)

NAVAIDS provide users important information and guidance in performing their missions. Information that can be requested from the NCS includes:

- bearing and range to an RS or a location identified as a grid coordinate
- guidance to and through a lane (a two-dimensional ground-based region defined by a series of linear segments)
- guidance to and through a corridor (a three-dimensional region defined with up to five legs used to provide airborne users with automatic one-way guidance over a predetermined course)
- guidance around a zone (a dimensional region having up to six sides used to indicate a restricted area)
- own or another RS's heading and speed
- own or another RS's position

- MGRS coordinates or bearing/range of PDIs.

4. Electronic Counter Countermeasures (ECCM)

EPLRS resists enemy jamming by using a variety of waveform design and signal processing techniques, relatively high values of effective radiated power (ERP) and a number of other factors such as automatic network configuration and path redundance. ECCM techniques used by EPLRS include burst transmission, spread spectrum, integral relay, error control and signal encryption. Its relay capability allows reliable radio coverage over large deployment areas with little prior relay planning. The system automatically selects a good relay path under conditions of rough terrain, limited line-of-sight or enemy jamming. [Ref. 3]

5. Capacity

Communication capacity at the network level is defined in terms of throughput and depends on the number of RSs in the network. For example, a network of 250 RSs comprised of 25% simplex and 75% duplex communications has a practical capacity of 180 Kbps. Needline and RS capacities are defined by their highest throughput. Group addressed needlines can support data rates up to 1200 bps; duplex needlines can support up to 600 bps. RS capacity for an individual duplex circuit is 640 bps for transmission or reception; group capacity on an individual circuit is 1280 bps.

D. OPERATIONAL FEATURES

1. Systems Control (SYSCON)

The EPLRS SYSCON is the operational focal point and technical controller of the multiple NCS community [Ref. 2 p. 14] and interfaces with higher level Information Systems Controls (ISYSCON). The ISYSCON ensures that the NCSs

operate in concert with each other. Major system control functions handled by the ISYSCON include "time and frequency resource allocation, time synchronization, crypto-key usage, CONOPS, communications with multiple NCS communities and the common library of units, needlines and NAVAIDS." [Ref. 2 p. 15] ISYSCON is responsible for providing the user community with the information necessary to utilize the system to its maximum potential and coordinates data transfer from each NCS to the users. Updated position, identification, NAVAID and needline information is provided over a group-addressed needline to a variety of host systems, including MCS and FAAD C^2I.

2. Needline activation

EPLRS needlines define which units exchange information, the data rate and priority of the exchange, and whether or not acknowledgement is required. Needline activation establishes data communications between two RSs or between an RS and multiple RSs (group-addressed). Needlines are assigned by the NCS and are activated by the user. User-to-user communication is established when a path is found and relay assignments are accepted by all RSs on the communication path.

3. Communications

EPLRS supports the near-term data requirements for the ADDS through a combination of duplex and group addressed communications using host-to-host (RS-to-RS) and free text message format. For host-to-host communications, needlines and needline parameters must be established prior to operations. User-to-user data communications over the control network requires no specific planning. An EPLRS communications circuit is a permanent virtual circuit between two or more RSs. For duplex needlines, the NCS assigns resources to support source and destination RSs. For

group addressed needlines, the NCS assigns specific resources to support a source RS and one or more destination RSs. The number of destination RSs is limited to 100 for group addressed needlines.

Both types of circuits use a second source receive technique by which a set of timeslots is assigned for all relays and destination RSs to listen for the transmissions through the chain. Using this technique, a final destination is able to hear a source transmission directly vice waiting for a relay. The redundancy provided by the automatic retransmission by the relay unit increases the probability of the final destination receiving the message.

4. Data delivery

ADDSI host packets or 1553B data blocks are converted by the RS into transmission units (TUs) containing 80 information bits each. The TUs are transported between source and destination RSs through the EPLRS communications network via needlines. The TUs are converted back to ADDSI packets or 1553B blocks at the destination RS. An ADDSI host can exchange data with a 1553B host as long as the information field formats are compatible.

5. Free Text Messages

The five categories of free text messages, distinguished by destination and delivery method are:

- *F:* messages between NCS and RS. These are ten character free text messages sent by the RS to the NCS and stored at the NCS.
- *G:* messages to the command and control center. The messages are automatically forwarded to the C2 center with the NCS functioning as a store and forward message switch.

- *R/Q:* messages between RSs via the NCS. R-type messages include the MILID of the destination unit. Each unit can predesignate a destination unit to automatically receive all Q-type messages from the originating unit. Each unit may be designated to receive Q messages from multiple other RSs.

- *S:* messages between RSs over a local subnet. Local subnets are independent of the control and communications networks and the NCS. They provide a faster and more reliable means of exchanging data across NCS community boundaries. Local subnets reduce the amount of traffic on the network control and provide faster response times than R/Q messages. However, they are limited to only one level of relay and only RSs assigned to the same local subnet will relay for each other.

- *Notices:* messages controlled and distributed by the NCS. These may be entered into the system or modified by any authorized unit. They are used for such things as weather prediction updates, alert level changes and mission status.

E. CURRENT STATUS

1. Basis of Issue

The current Basis of Issue authorizes 1816 Radio Sets, 23 Net Control Stations and 23 EPLRS Grid Reference Units. An additional 2107 RSs were authorized by the Army Acquisition Executive in September 1995. A "bridge" contract for 300 additional RSs was awarded 24 January 1996. EPLRS is currently fielded to the First Cavalry Division and to the 24th Infantry Division (Mechanized). [Ref. 4]

2. Battlefield Information Transmission System (BITS)

BITS is a direct outgrowth of the Army Digitization Master Plan (ADMP), which describes the process that will lead to seamless interoperability across the battlefield, the capability required to transform the Army into a 21st century force (Force XXI). [Ref. 5 p. 1] The goal of BITS is to develop a system that will exceed the current combined capacities of EPLRS and two other legacy systems, the Single Channel Ground

and Airborne Radio System (SINCGARS) and Mobile Subscriber Equipment (MSE) Tactical Packet Network (TPN). These three systems will form a Tactical Internet (TI) that will be "internetworked through the use of gateways to form a complete, seamless system for the brigade task force, division and corps AWEs." [Ref. 5 p. 5] BITS will use Asynchronous Transfer Mode (ATM) technology to increase throughput and interoperability and will connect to the Defense Information Systems Network (DISN).

The Near-Term Digital Radio (NTDR) is the initial BITS strategy to provide a system more capable but less expensive than EPLRS. The goal is to have a high data rate waveform that provides higher throughput than EPLRS. The far-term strategy includes experimentation with a prototype Future Digital Radio (FDR) and Wideband HF radios as a means of increasing capacity.

IV. OTHER SYSTEMS

There are a number of other situational awareness and combat identification systems currently in use or under development by the various services. This chapter briefly describes several such systems.

A. JOINT MARITIME COMMAND INFORMATION SYSTEM (JMCIS)

The Joint Maritime Command Information System was first conceptualized by SPAWAR PD60 in 1986. It has evolved to a system that uses the same software as the basis for both afloat and ashore communications. It is designed to provide a common operating environment (COE) for a core set of functions including track management, correlation, communications and tactical display components. This common software core is designed to provide standardization, increase interoperability, reduce training, and ensure that diverse systems providing the same function provide the same answers. JMCIS uses a client/server architecture in which clients establish a connection to and request services from a server and receive results back across the established connection.

JMCIS is comprised of eight core services: Alerts, Chart, Communications, File Management, Menu, Miscellaneous, Security and Track Management. Combat identification is primarily involved with the chart, communications and track management services. The chart service creates and manages tactical geographic displays. The communications service receives and processes incoming messages. The track management service includes basic track management, multiple track types, track correlation, and a track history archive. Tactical decision aids (TDAs) provided by JMCIS

include coordinate conversion, closest point of approach calculations, search and rescue pattern development, satellite database, satellite vulnerability calculations, status boards of selected tracks, and track history analysis. [Ref. 25]

B. GLOBAL COMMAND AND CONTROL SYSTEM (GCCS)

The Global Command and Control System is a highly mobile, deployable C2 system that will provide the Joint Chiefs of Staff (JCS) and Commanders in Chief (CINCs) with compatible, interoperable, and integrated C4I systems. It is designed to meet the C2 requirements of the National Command Authorities through the Joint Task Force Commander. The objective of GCCS is to provide the warfighter with the tools needed to accomplish his mission and the operational commander with the C2 system needed for the 21st century. It integrates tactical, theater and national intelligence from other C4I systems into a fused, common picture of the warfighter's battlespace. GCCS will essentially provide the backbone for all military and government communications traffic worldwide. [Ref. 22]

C. COMBAT TRACK

Combat Track is a program under development by the U. S. Air Force to provide enroute situational awareness of aircraft and logistics tracking. Combat Track uses military controlled relay satellites, the Global Positioning System and RF-tagged cargo pallets to provide position information, two-way message text, load plans and cargo information to users and control nodes. Data is relayed via encrypted UHF burst transmissions. Its TDMA structure supports up to 30 users with 10-second reporting slots and up to 900 users with a 5-minute reporting cycle. Combat Track is designed to be

compatible with the Army's Battlefield Distribution System. Its hardware includes a COTS laptop computer, transceiver, processor, SATCOM antenna, GPS antenna and an antenna interface. It is designed to be flown on any aircraft capable of being fitted with SATCOM and GPS antennas. [Ref. 26]

D. POSITION LOCATION REPORTING SYSTEM (PLRS)

The Position Location Reporting System has been used by the Marine Corps since 1987 as a means for a commander to monitor the movement of his maneuvering forces. It was designed to provide timely and accurate three dimensional positioning information, navigational assistance to friendly forces, coordinated fire and air support, and control and maneuver of ground and air units. Its major elements are master stations and user units. User units can be installed in aircraft, surface vehicles or manpacks. Like EPLRS, position location is computed using multilateration and is reported in MGRS coordinates. PLRS is a synchronous TDMA system that has a 64 second epoch as its longest user reporting period and a quarter-second frame as its shortest user reporting period. Each epoch is comprised of 256 frames; each frame is comprised of 128 timeslots; each timeslot is comprised of 2 msec. Its operating frequency is 420-450 MHz. For ECCM, PLRS uses spread spectrum, frequency hopping, error detection and correction and automatic relay. Its position accuracy is 15 meters CEP. [Ref. 27]

PLRS is being upgraded through the PLRS Communications Enhancement (PCE) program. This program is designed to provide Marine Corps units additional communications capability in support of current operations and emerging tactical systems. The PCE program will exploit the existing PLRS relay structure by providing several types

of communications service for a variety of tactical operations. It will also enhance the interoperability of PLRS and EPLRS by providing mutual relay support for EPLRS needlines.

Tests conducted on the USS ESSEX have demonstrated the capability to integrate PLRS with JMCIS to relay position locations and tracks of amphibious units to other ships and shore-based C2 nodes. [Ref. 19] The systems were integrated with a hard connection between the Navy Tactical Command System - Afloat (NTCS-A) and an AN/KSQ-1 amphibious assault direction finding system equipped with a GPS interface unit. The GPS interface unit allows AN/KSQ-1 platforms to transmit GPS data to a local workstation that reformats the position information from latitude/longitude to MGRS coordinates for retransmission to the PLRS master station. AN/KSQ-1 Block 1 is an upgrade planned for FY97 to completely integrate PLRS with JMCIS, enabling all ships in a task force to receive the PLRS-derived position location information.

E. GRENADIER BRAT

Grenadier Brat is an Army TENCAP initiative to produce a small, low power, LOS/SATCOM capable reporting beacon that uses GPS for position location and the Cobra waveform for communications. It provides LPI/LPD, one-way communications from its beacons to its C2 terminal. As of August 96, Grenadier Brat was the only situational awareness system with the Cobra waveform. [Ref. 21]

V. PROGRAM DEMONSTRATIONS

A. ALL SERVICE COMBAT IDENTIFICATION TEAM 1995 (ASCIET 95)

SABER was evaluated as part of the ASCIET 95 assessment of combat identification systems as directed by the Joint Requirements Oversight Council (JROC). The evaluations were conducted 27 August 1995 to 17 September 1995 with the support of the Joint Command and Control Warfare Center (JC2WC) and various operational units at Eglin AFB, FL. The purpose of ASCIET is to examine current multi-service combat identification procedures and capabilities on the battlefield and to identify possible changes to systems, interoperability issues, doctrine, tactics, techniques and procedures. The findings and recommendations of ASCIET are included in the General Officer Steering Group - Combat Identification (GOSG-CID) annual report to the JROC and Commanders-in-Chief. [Ref. 9]

1. ASCIET 95 Goals

The goals of SABER's participation in ASCIET 95 included:

- Demonstrate how timely utilization of SABER-derived information can increase friendly force situational awareness prior to an engagement.
- Demonstrate the capability to decrease the incidence of fratricide when SABER-derived information is used.
- Demonstrate increased situational awareness by theater level operators when using SABER.
- Compare SABER's responses with those provided by other combat identification programs.

2. Positive findings

Naval Space Command concluded that SABER's potential value in the prevention of fratricide and command and control of forces was clearly demonstrated in ASCIET 95. They concluded that SABER "provided improved situational awareness for the warfighter and the battleforce commander, it mitigated fratricide through knowledge of the battlespace and FID, and the system proved itself to be sufficiently mature for an extended operational evaluation." [Ref. 14] Their findings included:

- SABER accuracy was within 100 meters for latitude/longitude and 100 meters for altitude.
- SABER navigated over 95 percent of the time and communicated over 98 percent of the time over operational routes that included open areas, heavy foliage and urban environments.
- The SABER C2 terminal was able to display and distinguish two beacon-equipped platforms separated by as little as 10 meters.
- Response time from ITS to DSM was 1 to 6 seconds using half-duplex communications.

3. Negative findings

Shortcomings identified during ASCIET 95 included:

- OTCIXS cannot support the additional reporting required to support the SABER.
- The prototype beacon cannot support more than 100 beacons when reporting of more than once per minute via LOS or once per 5 minutes via SATCOM is required.
- When providing situational awareness and control functions, a single transceiver provide insufficient resources for an FID net.

B. 22 MEU DEPLOYMENT

A Marine Expeditionary Unit (MEU) is an amphibious readiness force that is prepared for employment across a wide spectrum of operational and crisis situations. Naval Space Command deployed a SABER system with the Twenty-Second Marine Expeditionary Unit (22 MEU) to the Mediterranean Ocean 27 January 1996. The system deployed included one C2 terminal located on the USS GUAM, eighteen SABER beacons mounted on various tactical vehicles and aircraft and one manpack. SABER was deployed with 22 MEU to provide feedback on the merits of SABER technology and to verify its utility to Marine Corps Amphibious Readiness Group operations. [Ref. 29]

1. 22 MEU Goals

The goals of this SABER deployment included [Ref. 29]:

- Determining if SABER improves friendly force situational awareness for the warfighter.
- Determining if SABER does indeed demonstrate a feasible approach to mitigating the combat fratricide problem.
- Determining if SABER is sufficiently mature to support expanded use by operational forces.

2. Positive Findings

22 MEU reported that "overall, SABER performed as advertised throughout the deployment, contributing significantly to the improved situational awareness of the MEU commander and his staff." [Ref. 15]. Specific findings included:

- SABER was seamlessly integrated into the C2 architecture of 22 MEU, the George Washington battlegroup, Sixth Fleet and EUCOM.
- The system possesses the fundamental characteristics that will enable it to be integrated into tactical communications.
- The system was easy to mount and install on a variety of platforms.

3. Negative Findings

22 MEU reported that a troubling aspect of SABER is its reliance on SATCOM. They were unable to secure a dedicated SATCOM channel for any of the scheduled exercises or real world operations. While the system functioned properly in the UHF LOS mode, a lack of available SATCOM channels made it difficult to meet the needs of the operational commander during over-the-horizon operations. [Ref. 15]

C. ALL SERVICE COMBAT IDENTIFICATION TEAM 1996 (ASCIET 96)

SABER was tested in ASCIET 96 as an "off-line" system, meaning that the ASCIET staff was not formally involved in its assessment and that SABER testing would be conducted on a not-to-interfere basis with the "on-line" activities. The same SABER-0 beacons that were used for ASCIET 95 and the 22 MEU deployment were also used for ASCIET 96. In addition to verifying results obtained from previous SABER demonstrations, ASCIET 96 was used to assess the interoperability of SABER with EPLRS and Grenadier Brat. [Ref. 21]

The SABER network consisted of a control tower with C2T controllers for both LOS and SATCOM networks, a repeater and nine ground beacons. The EPLRS net consisted of an NCS, several reference stations and approximately 140 RSs. Approximately 24 Grenadier Brat beacons were used, four of which were collocated with SABER beacons. Connectivity between SABER and EPLRS was achieved by establishing a needline from an EPLRS RS located in the SABER control center to the EPLRS NCS. An EPLRS Situational Awareness Terminal (SAT) was used as a gateway between EPLRS and SABER. An RS-232 serial link connected the EPLRS SAT and SABER C2T

to bring EPLRS platforms into the SABER net and pass SABER/Grenadier Brat positions to EPLRS. A closely related off-line study linked EPLRS-equipped F-16s to the EPLRS net via SADL.

1. ASCIET 96 Goals

Goals for SABER in ASCIET 96 included the following [Ref. 21] :

- Determine if SABER provides improved SA for the warfighter.
- Determine if SABER demonstrates a feasible approach to mitigating the combat fratricide problem.
- Determine if SABER is sufficiently mature for an extended operational evaluation.
- Determine if SABER data can be fused with information from other C2 sources to form a common operational picture for the warfighter.

2. Positive Findings

Naval Space Command found that "functionally the SABER/EPLRS/Grenadier Brat Common Operating Picture was a success." [Ref. 21] ASCIET 96 confirmed the position location accuracy displayed in ASCIET 95. Additional positive findings of ASCIET 96 were:

- SABER demonstrated capability to generate six reports per minor frame over the 25 kHz SATCOM channel.
- The SABER C2T demonstrated the ability to display relative position and spatial separation of beacons on various digital map displays.
- SABER successfully activated pre-programmed missions, reprogrammed beacon configuration and commanded beacons through both the 25 kHz UHF SATCOM net and the LOS net.
- The SABER C2T demonstrated the ability to actively display 70-80 SABER/EPLRS/Grenadier Brat tracks (a number three times that previously tested).

- SABER demonstrated connectivity to SIPRNET, OTCIXS, JTIDS and EPLRS.

- SABER data broadcast on the EPLRS net, fused with EPLRS and displayed on the EPLRS SAT was accurate and timely.

- The ability to have SABER/EPLRS positions sent/received via SADL to the F-16 was confirmed.

- The ability to fuse EPLRS data pulled from the EPLRS net with SABER and display it on the SABER C2T was confirmed.

- The ability to send Cobra data from the Grenadier Brat C2T to the SABER C2T was confirmed.

3. Negative Findings

Several areas that still require refinement were identified [Ref. 21]:

- SABER has a sensitivity problem with the 5 kHz SATCOM channel in a strong RF environment. Local RFI and high power users can knock SABER off this channel.

- Since no SABER C2T controller owns the entire capability of a beacon, it is not possible to use one net to change the program of a LOS net on a beacon that is not accessible to its LOS controller.

- The CDTs used for ASCIET 96 are not suitable for operational environments.

- A large number of EPLRS position reports sent from the SAT to the SABER C2T were lost, resulting in poor timeliness.

- Grenadier Brat position reports sent to the SABER C2T were 20-25 seconds time-late.

- EPLRS data rebroadcast on the SABER net, fused with SABER data and displayed to the SABER C2T in LSA mode experienced a significant time-lag.

- Grenadier Brat data rebroadcast on the SABER net, fused with SABER data and displayed to the SABER C2T in LSA mode experienced a significant time-lag.

D. JOINT WARRIOR INTEROPERABILITY DEMONSTRATION 1996 (JWID 96)

JWID 96 was also conducted in August 1996. The exercise focused on demonstrating the capability to provide a real-time, single picture common operating environment to the warfighter using a low cost system. The exercise demonstrated the capability to inject position location information PLRS and EPLRS-equipped units into GCCS and JMCIS using EHF communications via the MILSTAR satellite system. Additionally, EPLRS tracks were simultaneously transmitted to an Air Force controller to provide near-real-time situational awareness to pilots flying close air support. [Ref. 28]

VI. PROPOSED CONCEPTS OF OPERATIONS

A. COMPARISON OF SABER AND EPLRS CHARACTERISTICS

Before looking at possible architectures for integrating SABER and EPLRS, it is important to understand the programs' similarities and differences. SABER is designed to provide a quick snapshot of the battlefield to the tactical user. EPLRS is a legacy system designed to provide tactical situational awareness as well as to provide real-time communications between tactical users operating within a common area. Both SABER and EPLRS are relatively lightweight, transmit over similar frequencies using similar ECCM techniques, and provide comparable position location accuracies. However, the systems use different position location methods and coordinate systems, and have different transmission time intervals. Additionally, there is a significant difference in the projected costs of the systems. The projected cost of a SABER beacon is $5K while the projected cost of an EPLRS radio set is $30-40K. [Ref. 13] Table 4 summarizes the similarities and differences of the two programs.

SPECIFICATION	SABER-1	EPLRS
Electrical Voltage	18-35 Vdc, 15W receive, 200 W transmit, plus enhanced power management for manpack	28 Vdc, 16W
Radio Size	8 pounds Length: 8 inches Width: 10 inches Height: 3 inches	Radio Set: 17 pounds Total RS (battery, antenna, display): 28 pounds Length: 14.7 inches Width: 10.5 inches Height: 5.1 inches
Antenna Type	SATCOM/LOS: Monopole, Crossed Dipole GPS: 3" diameter active patch	LOS: Monopole
Frequencies	UHF 243-400 MHz	UHF 420-450 MHz
ECCM	Burst, FEC, COBRA waveform, frequency agile, NSA certified crypto	Spread spectrum, frequency hopping, error detection and correction
Position Display on Vehicle	User identification, latitude, longitude, altitude, COG, SOG	MGRS (text only)
Data Distribution	JTIDS, Link 16, OTCIXS, OTHGOLD, TRAP	Integrated Communication System Controller, STDN-4, SCAMP, Link 4A, Link 11, Link 16
Software Diplays	JMCIS, Unified Build, Military and commercial maps at C2T, CDT and TALON TAC-4 C2 Terminal	Network situational awareness at NCS, JMCIS display via PLIS
Integrated with and Displays Tracks On	JMCIS, GCCS, OTCIXS, TRAP, TAC-3 C2 compatible and interoperable	IVIS, SINGCARS, JMCIS, SADL
Maximum Number of Users	15,000 position updates per hour SATCOM, 60,000 per hour LOS, 10 networks	250 radio sets and 1 NCS per brigade area, potential of up to 460 RSs
Transmission Interval	Flexible, as fast as 200 msec SATCOM, 50 msec LOS	Controlled by NCS based on rate of movement, as fast as 250 msec
Time Delays	Real-time updates via SATCOM/LOS	Info requests granted as fast as 1 sec
Modulation	BPSK, FEC coded 256-bit burst transmission (128 info bits), COBRA waveform	Spread spectrum, frequency hopping, 94-bit burst transmission (80 info bits)
Position Accuracy and Method	<16m SEP when keyed GPS P(Y) Code	15m CEP Multilateration
Communication Ports	RS-232, KYK-13/KOI-18, MIL-STD-1553B	X.25, MIL-STD-1553B

Table 4: SABER/EPLRS Comparison Matrix [Ref. 13].

B. ALTERNATIVE CONCEPTS OF OPERATIONS

The goal of integrating SABER and EPLRS is to provide a common operating picture to all warfighters. Any integration plan will require modifications to both systems. Items that must be considered are the position location method and reporting system used, reporting architectures, and overall connectivity. The following concepts of operations (CONOPS) are proposed for integrating SABER and EPLRS. All options are based on the assumption that EPLRS units will continue operating with other EPLRS units according to already established protocols and that SABER units will communicate with other SABER units as previously established.

1. Option 1: Collocation of SABER Beacon with EPLRS Radio Set

The first option would be to collocate a SABER beacon with every EPLRS radio set. Every unit would then report via both systems. This would allow each unit to respond to every ITS message as well as maintain communications with the EPLRS Net Control Stations. Figure 9 shows this CONOP.

This would be a simple, although costly and somewhat redundant, solution if EPLRS and SABER used the same position reference system. However, since SABER uses GPS and EPLRS uses MGRS, this solution could not be implemented without a software upgrade for either the EPLRS RSs or the SABER beacons. Additionally, since there is not a SABER beacon located at the NCS, it would require the RS user to be proficient in the operation of both systems and would place on the user the added burden of providing a timely response to both systems simultaneously.

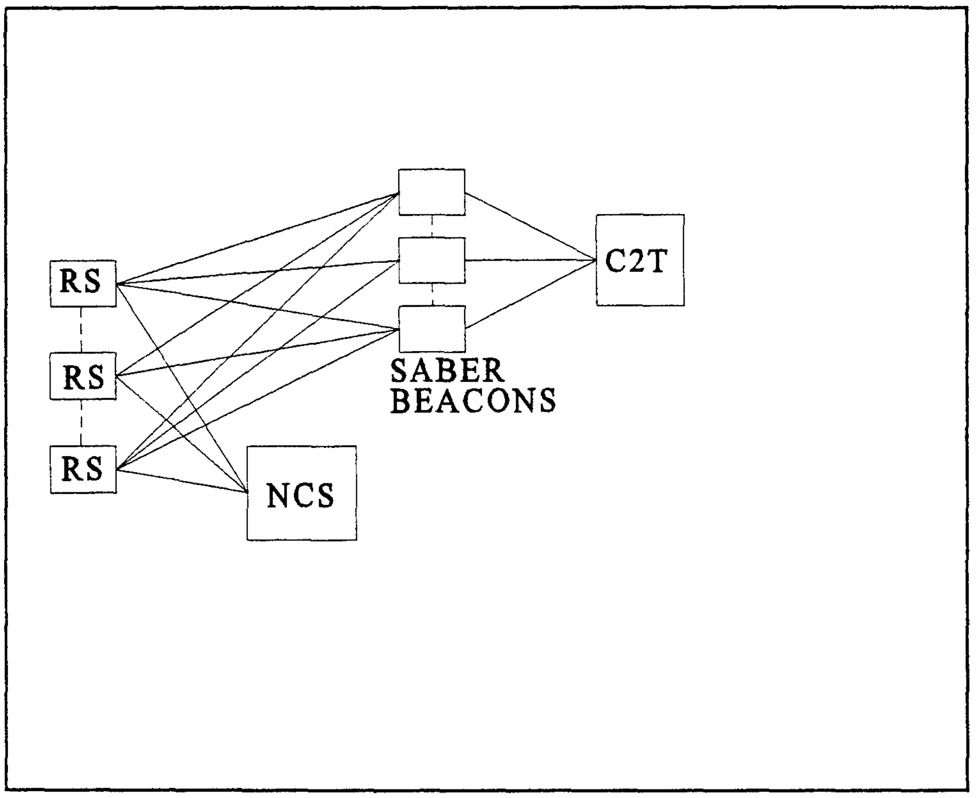


Figure 9: EPLRS/SABER CONOP Option 1.

2. Option 2: Collocation of SABER Beacon at EPLRS Net Control Station

The second option is to place a SABER beacon at the EPLRS Net Control Station vice at the RSs. The RSs would report to the NCS, as they do now. The NCS would be configured to respond to individual SABER ITS messages based on all positional information currently available on the RSs connected to the NCS. It could be configured to provide either a generic Don't Shoot Me message based on the presence of RSs in the targeted area or a detailed response with unit identifications and exact positions.

To accomplish this, the NCS would require the capability of converting incoming EPLRS RS MGRS coordinates to latitude/longitude prior to responding to a SABER ITS message. This option would eliminate the redundant reporting by the RSs, as needed for Option 1. Figure 10 shows this CONOP.

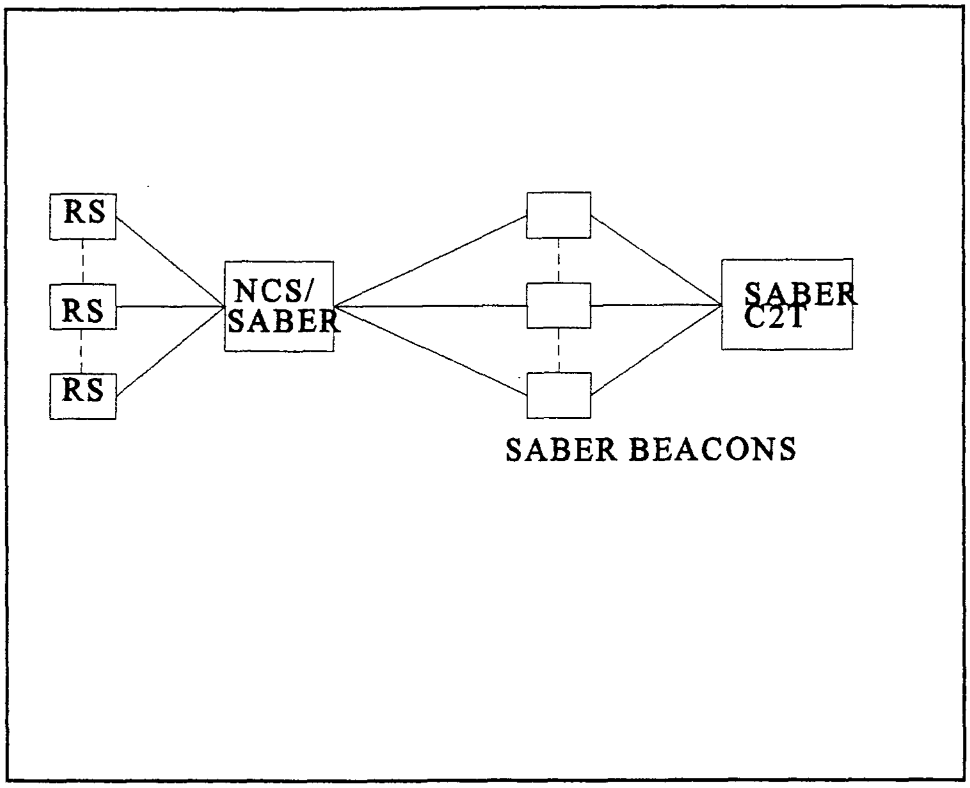


Figure 10: EPLRS/SABER CONOP Option 2.

3. Option 3: Modify SABER C2Ts to Convert Coordinates

A third option is to modify the SABER C2Ts to receive EPLRS positional information in MGRS coordinates, from either individual RSs or as a compilation from the NCS, and convert the positions to latitude/longitude prior to forwarding it to SABER-equipped units. This would place the direct burden of responding to ITS messages on the C2Ts. The RSs or NCSs could be configured to provide routine updates of all EPLRS

units to the SABER C2Ts. The C2Ts could be programmed to provide either a generic DSM message based on the reported presence of friendly units in the targeted area or a detailed response with unit identifications and exact positions. Figure 11 shows this CONOP.

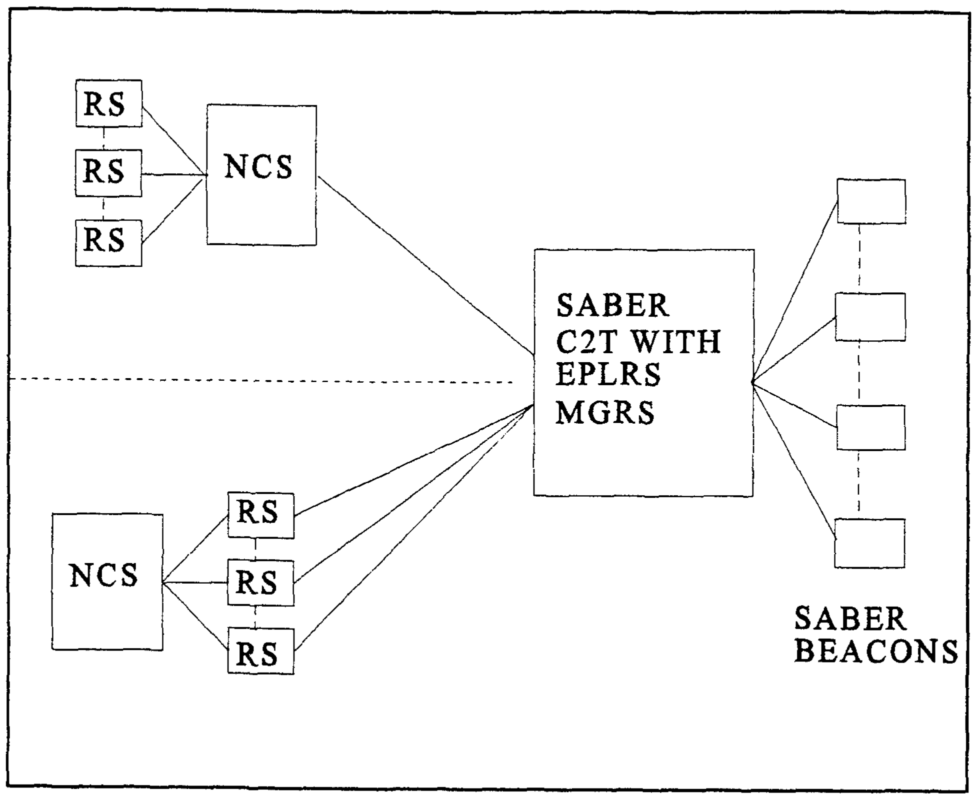


Figure 11: EPLRS/SABER CONOP Option 3.

4. Option 4: Super C2T

The fourth option would require all SABER and EPLRS positional information to be passed to a common C2T. This "super C2T" would function as a situational awareness clearinghouse and compare all positional information from all sources. As with Option 3, this option could be configured in one of two ways. With the first method, the NCS would forward data from its reporting RSs. With the second

method, individual RSs would be linked to the C2T as well as to their NCS. Upon receipt of an ITS message from a SABER-equipped unit, this super C2T could respond with a basic positive/negative report indicating the presence of any friendly units in the targeted area. It could also be programmed to provide unit identification and positional information of the units in this area. Figure 12 shows this CONOP.

While this might be a good option for conducting post-event analysis and for relaying a snapshot of the battlespace up the chain of command, it would probably not meet the timeliness required for combat identification.

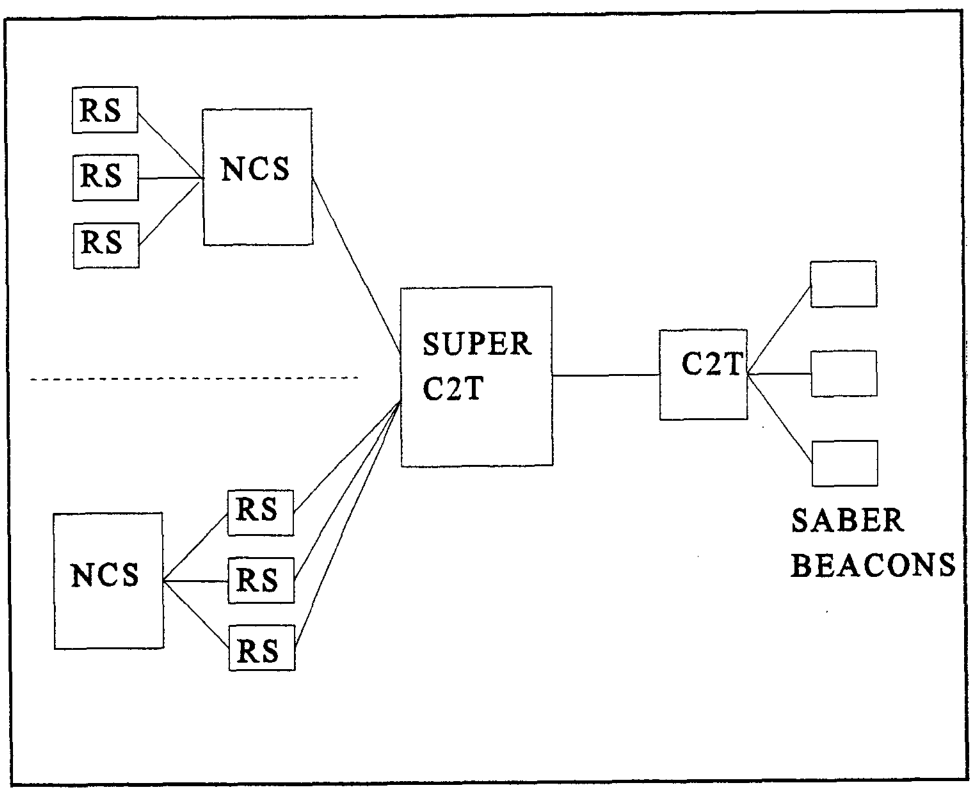


Figure 12: EPLRS/SABER CONOP Option 4.

C. RECOMMENDED CONCEPT OF OPERATIONS

The largest issue involved with integrating SABER and EPLRS is determining what coordinate system will be used. The best long term SABER-EPLRS solution is to embed a GPS receiver into each EPLRS radio set and modify EPLRS to use standard latitude/longitude coordinates. This, however, is a costly undertaking. Until it happens, we must look at the best way to convert from the MGRS coordinates used by EPLRS to the latitude/longitude coordinates used by SABER.

Based on the pros and cons of each option discussed above, Option 3 appears to be the best solution. It is far easier and much less costly to modify the SABER C2Ts to perform the function of coordinate system conversion than it would be to modify the already fielded EPLRS radio sets and net control stations.

1. EPLRS to SABER Data Flow

Since EPLRS RSs communicate via line of sight with their NCSs, but are most likely not within LOS of the SABER C2T, the most sensible solution is for the NCSs to transmit the positional updates to the SABER C2T. The NCSs should compile and forward an update of the locations, in MGRS coordinates, of all EPLRS-equipped units to the SABER C2T in accordance with a pre-established schedule. Additionally, the NCS should be able to provide updates as requested by the C2T. The C2T should be configured to convert MGRS coordinates to latitude/longitude coordinates prior to responding to a SABER beacon's ITS message. The C2T can be programmed to provide several different types of responses to an ITS message. It can send a message that says (1) it's okay to shoot - there are no friendly units within the targeted area, (2) there are friendly units within the intended targeted area (a generic DSM message), or (3) friendly

units are located at latitude/longitude (a standard specific DSM message). The SABER-equipped unit can then take action accordingly. Figure 13 portrays the data flow for this envisioned CONOPS.

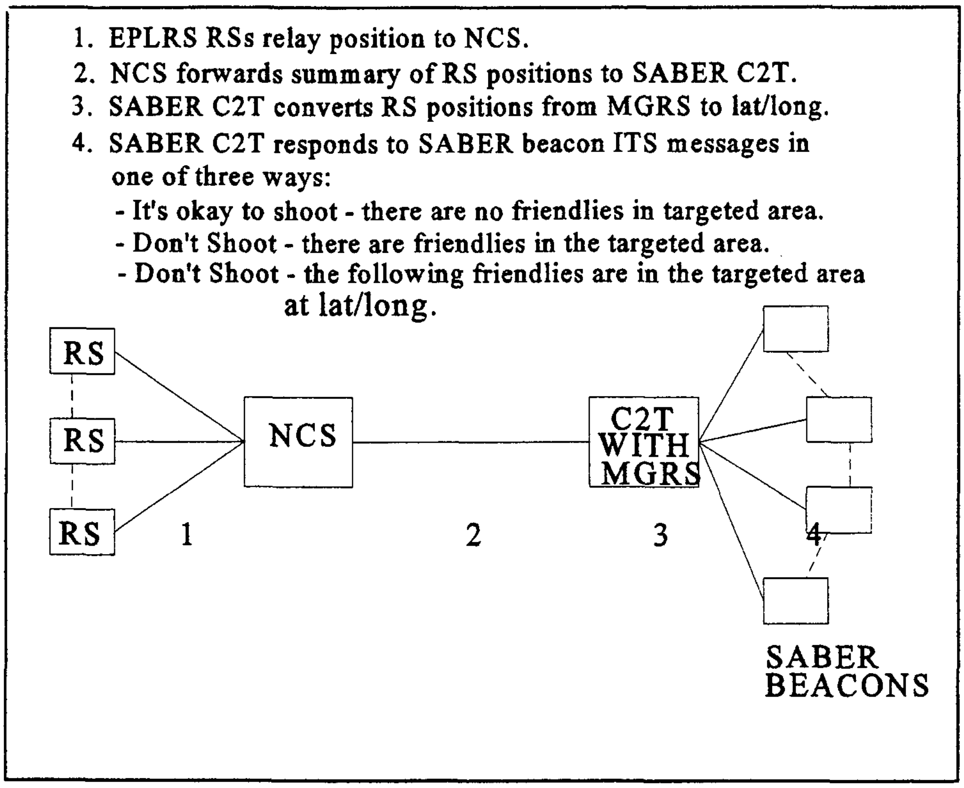


Figure 13: Recommended CONOPS: EPLRS to SABER Data Flow.

2. SABER to EPLRS Data Flow

To enable the EPLRS-equipped units to have the same overall picture of the battlefield as the SABER-equipped units, the SABER C2T should also be configured to convert the latitude and longitude coordinates received from the SABER beacons to MGRS coordinates. It can then relay the positions of SABER-equipped units to the EPLRS NCSs for further relay to the RSs. Figure 14 portrays this data flow.

1. SABER beacons transmit their positions to C2T.
2. C2T converts beacon positions from lat/long to MGRS.
3. C2T relays beacon positions to EPLRS NCS.
4. NCS relays SABER positions to RSs.

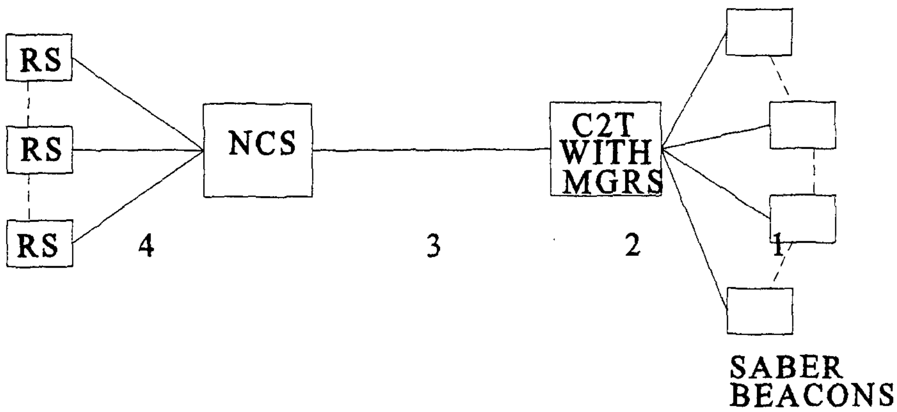


Figure 14: Recommended CONOPS: SABER to EPLRS Data Flow.

VII. INTEGRATED SITUATIONAL ASSESSMENT CONOPS

The projected cost of SABER is $5K per unit. The projected cost of EPLRS is $30-40K per unit. [Ref. 13] Based on these numbers alone, it can be argued that the ultimate combat identification solution is to cancel EPLRS and install a SABER beacon on every tank, aircraft, and ship. However, the services must look beyond these numbers and determine the exact requirements. SABER and EPLRS are only two pieces of the combat identification/situational awareness equation. Other CID systems currently in use/under development, such as those discussed in Chapter IV, must also be considered. There may not be a need for both SABER and Combat Track. Or, there may be a requirement to integrate SABER with PLRS as well as EPLRS to capitalize on the efforts already made to integrate PLRS with JMCIS. [Ref. 19]

The services must take a hard look at all of these systems and determine the best way to provide the current tactical picture to the front-line tactical units, joint task force commanders and remotely located commanders. They need to determine exactly who needs the information and how often it really needs to be updated. In other words, are near-real time information updates actually required for everyone? Additionally, while the services must ensure the warfighters have all the information required to make tactical decisions, they must also look at the ramifications of providing them too much information. Creating an information overload can create confusion and be as detrimental as not providing enough information.

Once the actual combat identification/situational awareness requirements are determined, the services must look at the communications infrastructure needed to support them. Near-real time updates require dedicated, jam-proof communications links. While integrating SABER and EPLRS goes a long way toward answering combat identification needs, this combination will not work without the communications architecture to support it. SABER has been designed to utilize FLTSATCOM, however, there is a limit to the number of communications channels that can be provided by the satellites currently in orbit. Other communications options, including the use of MILSTAR and the costly option of placing more satellites in orbit, must be explored.

If the goal is to completely integrate all of the situational awareness systems, CONOP Option 4: Super-C2T (discussed in Chapter IV) must be given serious consideration. This Super-C2T could provide the common gateway needed to allow the exchange of CID information from a variety of systems. Since the AN/KSQ-1 Block 1 upgrade planned for FY 97 will integrate the amphibious assault direction finding system with PLRS and JMCIS [Ref 19], thus answering the question of how to convert from GPS coordinates to MGRS coordinates, JMCIS should be considerd for the role of Super-C2T. Figure 15 depicts a CONOPS encompassing the situational awareness systems and possible communications links.

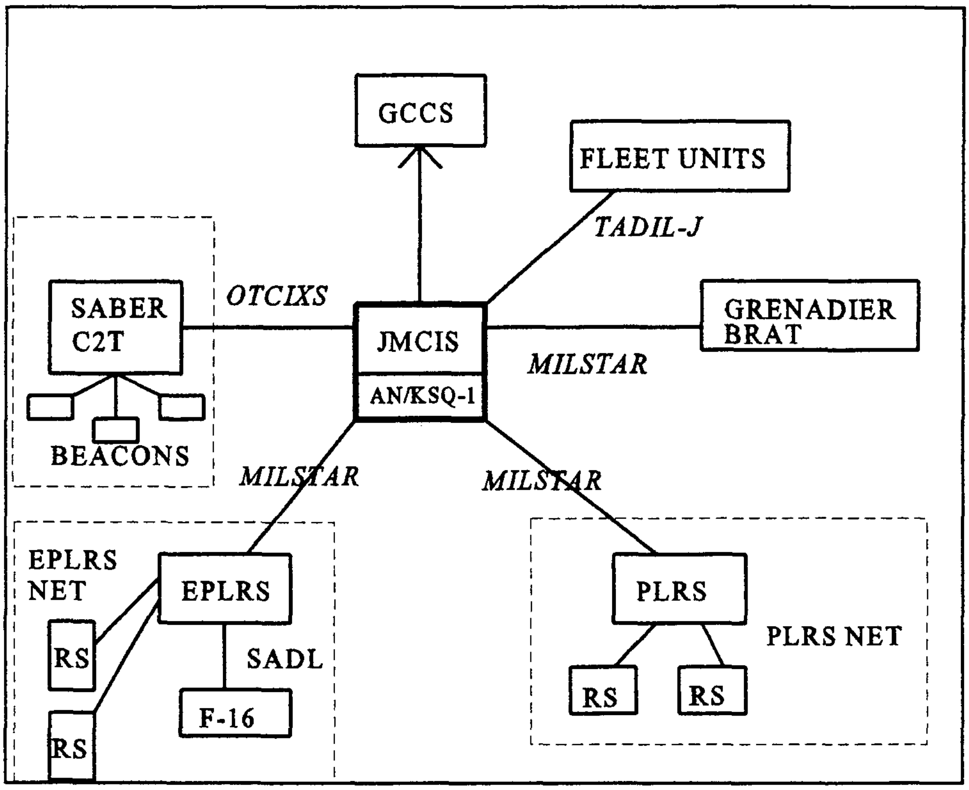


Figure 15: Situational Awareness Systems CONOPS.

With this architecture, all combat identification/situational awareness systems are linked to JMCIS. JMCIS would then act as a clearinghouse, converting MGRS coordinates to latitude and longitude, and vice versa. It would provide each CID/SA system access to the databases of all other CID/SA systems. This architecture would allow any JMCIS-linked command to obtain a quick view of any aspect of the battlefield. It would greatly increase the commander's knowledge and facilitate a timely, better-informed response to changing battlefield conditions.

Combat identification and situational awareness systems cannot be created in a vacuum. With the joint requirements and budget constraints of today, these systems must be designed to be interoperable with current systems as well as with other systems under

development. Program managers must have firsthand knowledge of programs and efforts similar to their own programs and must take the initiative to ensure that time and money are not wasted on duplicate programs. Better lines of communications must be established between the services and between various commands and organizations within the same service. Commanders and warfighters need a common operational picture of the battlefield. The integration of SABER and EPLRS is a major step toward achieving this goal.

APPENDIX A: FREQUENCY DEFINITIONS

Signals used for satellite communications are normally in the UHF, SHF and VHF frequency ranges. Unlike HF and lower frequencies, UHF, SHF and VHF signals propagate along straight-line paths and are virtually unaffected by the ionosphere. [Ref. 20, p.233] SABER and EPLRS both use UHF frequencies. The table below summarizes the radio frequency spectrum.

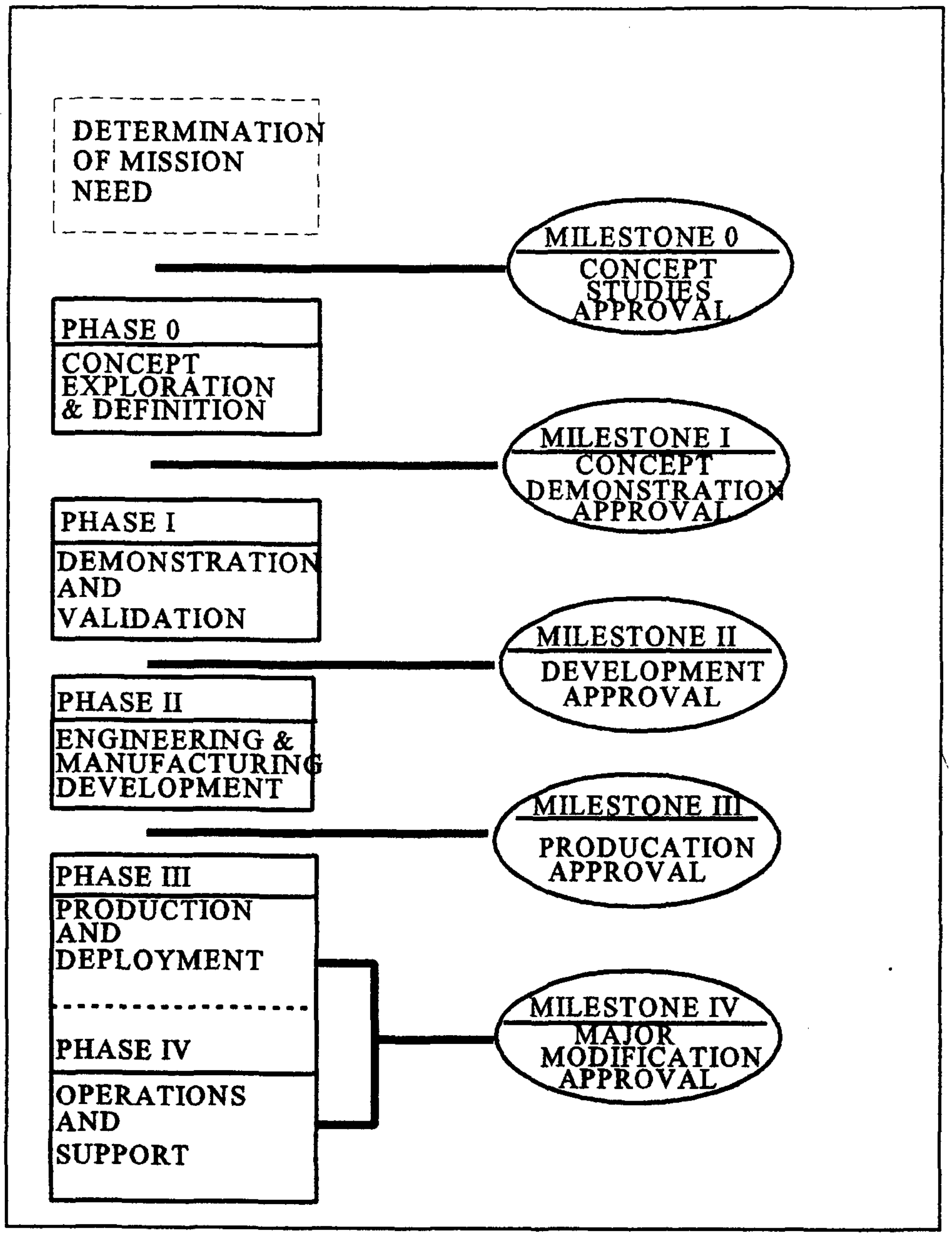
ELF	Extremely Low Frequency	30 Hz - 300 Hz
VF	Voice Frequency	300 Hz - 3 kHz
VLF	Very Low Frequency	3 kHz - 30 kHz
LF	Low Frequency	30 kHZ - 300 kHz
MF	Medium Frequency	300 kHz - 3 MHz
HF	High Frequency	3 MHz - 30 MHz
VHF	Very High Frequency	30 MHz - 300 MHz
UHF	Ultra High Frequency	300 MHz - 3 GHz
SHF	Super High Frequency	3 GHz - 30 GHz
EHF	Extremely High Frequency	30 GHz - 300 GHz

APPENDIX B: DATA LINKS

There are a number of different data links used to relay tactical information between ships, aircraft and shore nodes. One of the issues involved with integrating SABER and EPLRS is determining how the CID data will be passed over these links. The table below [from Ref. 20] lists the characteristics and uses of common tactical data links.

NATO Format	U. S. Designation & Format	Data Rate	Frequency Band	Use
Link 1	TADIL B	2.4 kbps	landline	air defense
Link 4A	TADIL C	5 kbps	UHF	aircraft data system
Link 11	TADIL A	2.25 kbps	HF	NTDS
Link 14	TADIL A	75 bps	HF/UHF	NTDS
Link 16	TADIL J	28.8 kbps, 57.6 kbps or 115.2 kbps	UHF	JTIDS

APPENDIX C: ACQUISITION MILESTONES AND PHASES



[After Ref. 30, p. 2-1]

APPENDIX D: ACQUISITION CATEGORIES AND MILESTONE DECISION AUTHORITIES

ACAT	SELECTION CRITERIA	DESIGNATION AUTHORITY	MILESTONE DECISION AUTHORITY
I	A program not classified as highly sensitive by the Secretary of Defense that has been designated as an ACAT I program or has been estimated by the Under Secretary to require an eventual expenditure of more than $300 million for RDT&E or more than $1.8 billion for procurement (measured in FY 1990 constant dollars).	Under Secretary of Defense (Acquisition) ACAT I D - Under Secretary ACAT I C - Component Head	ACAT I D - Under Secretary of Defense (Acquisition) ACAT I C - DoD Component Head or, if delegated, the DoD Component Acquisition Executive
II	A program not meeting the criteria for ACAT I that has been designated by the DoD Component Head as an ACAT II program or is estimated to require an eventual expenditure of more than $115 million for RDT&E or more than $540 million for procurement (measured in FY 1990 constant dollars).	DoD Component Head or, if delegated, the DoD Component Acquisition Executive	DoD Component Head or, if delegated, the DoD Component Acquisition Executive
III	Programs not meeting criteria for ACAT I and ACAT II that have been designated ACAT III by the DoD Component Acquisition Executive.	DoD Component Acquisition Executive	Lowest level deemed appropriate by the designation authority
IV	All other acquisition programs for which the milestone decision authority should be delegated to a level below that required for ACAT III.	DoD Component Acquisition Executive	Lowest level deemed appropriate by the designation authority

[After Ref. 30 , p. 2-3]

APPENDIX E: ACRONYM LIST

ACAT	Acquisition Category
ADMP	Army Digitization Master Plan
APA	Airborne Power Adapter
ASCIET	All Service Combat Identification Evaluation Team
ATM	Asynchronous Transfer Mode
BPSK	Binary Phase Shift Keying
C2	Command and Control
C2I	Command, Control and Intelligence
C2T	Command and Control Terminal
C4I	Command, Control, Communications, Computers, and Intelligence
CDT	Command Display Terminal
CEP	Circular Error Probable
CID	Combat Identification
COE	Common Operating Environment
CONOP	Concept of Operations
DDN	Defense Data Network
DSM	Don't Shoot Me
DSP	Digital Signal Processor
ECCM	Electronic Counter Countermeasures
EPLRS	Enhanced Position Location Reporting System
ERP	Effective Radiated Power
EUCOM	European Command
FDMA	Frequency Division Multiple Access
FDR	Future Digital Radio
FEC	Forward Error Correction
FID	Friendly Identification
FLTSATCOM	Fleet Satellite Communications
FSK	Frequency Shift Keying
GOSG	General Officer Steering Group
HMMWV	Highly Mobile Multipurpose Wheeled Vehicle
IFF	Identification Friend or Foe
ISYSCON	Information Systems Control
JC2WC	Joint Command and Control Warfare Center
JMCIS	Joint Maritime Command Information System
JROC	Joint Requirements Oversight Council
JTIDS	Joint Tactical Information Data System
JWID	Joint Warrior Interoperability Demonstration
LOS	Line of Sight
LPD	Low Probability of Detection
LPI	Low Probability of Interception
LSA	Local Situational Awareness
MEU	Marine Expeditionary Unit

MGRS	Military Grid Reference System
MILID	Military Identification
MILSATCOM	Military Satellite Communications
MSE	Mobile Subscriber Equipment
NAVAID	Navigation Aid
NCS	Network Control Station
NCTS-A	Naval Command Tactical System - Afloat
OTAR	Over the Air Rekeying
OTCIXS	Officer in Tactical Command Information Communications System
OTH	Over the Horizon
PDI	Predesignated Item
PLE	PLRS Communications Enhancement
PLRS	Position Location Reporting System
RFI	Radio Frequency Interference
RS	Radio Set
SABER	Situational Awareness Beacon with Reply
SADL	Situational Awareness Data Link
SATCOM	Satellite Communications
SEP	Spherical Error Probable
SITREP	Situational Report
SYSCON	Systems Control
TBD	To Be Determined
TDA	Tactical Decision Aid
TDMA	Time Division Multiple Access
TENCAP	Tactical Exploitation of National Capabilities
TI	Tactical Internet
TID	Target Identification
TOA	Time of Arrival
TPN	Tactical Packet Network
TRAP	Tactical Related Applications
TU	Transmission Unit

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